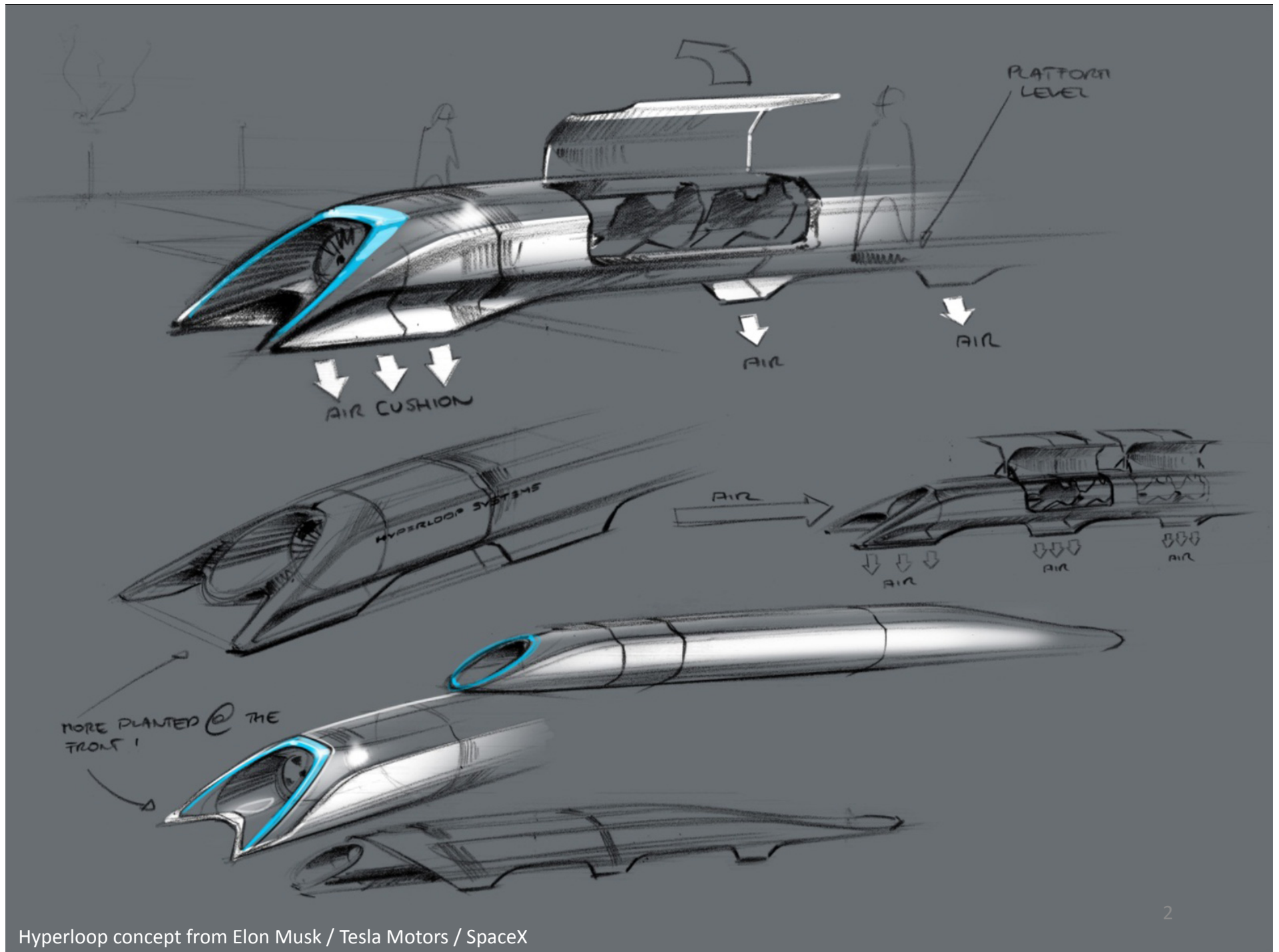
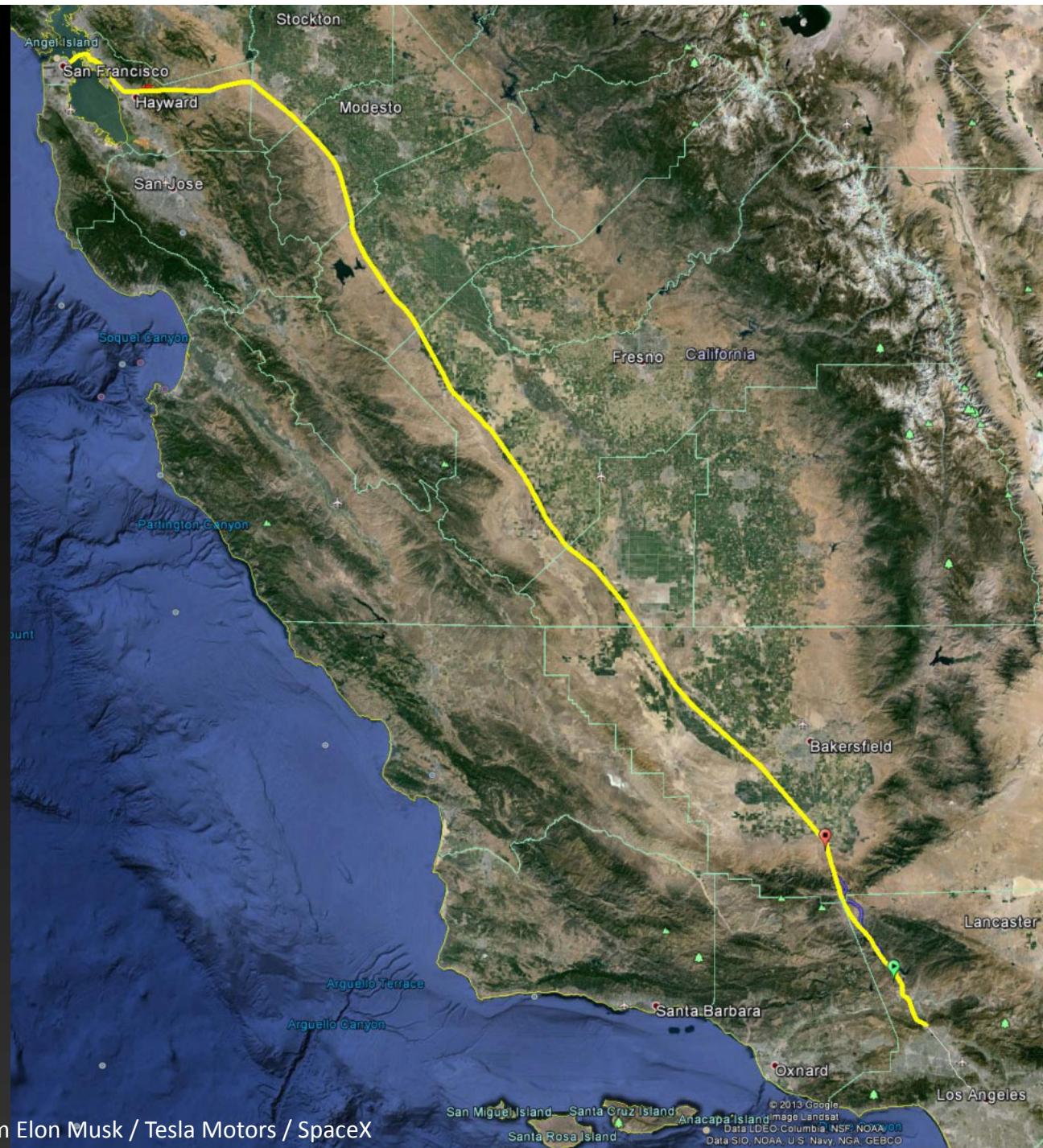


# Hyperloops, Nuclear Spacecraft, and the New York City Subway

Stephen Granade  
Dynetics, Inc.

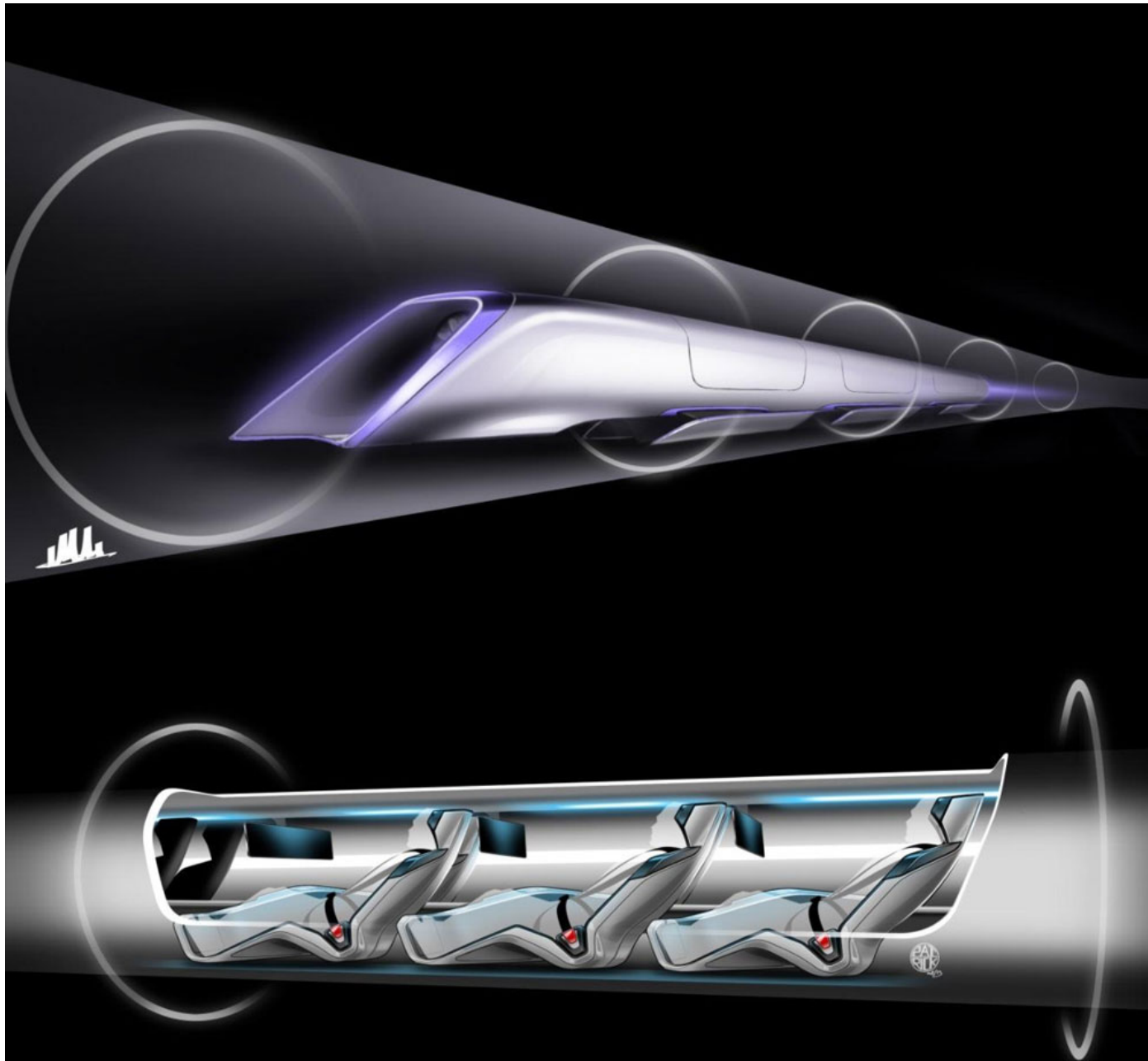


Hyperloop concept from Elon Musk / Tesla Motors / SpaceX



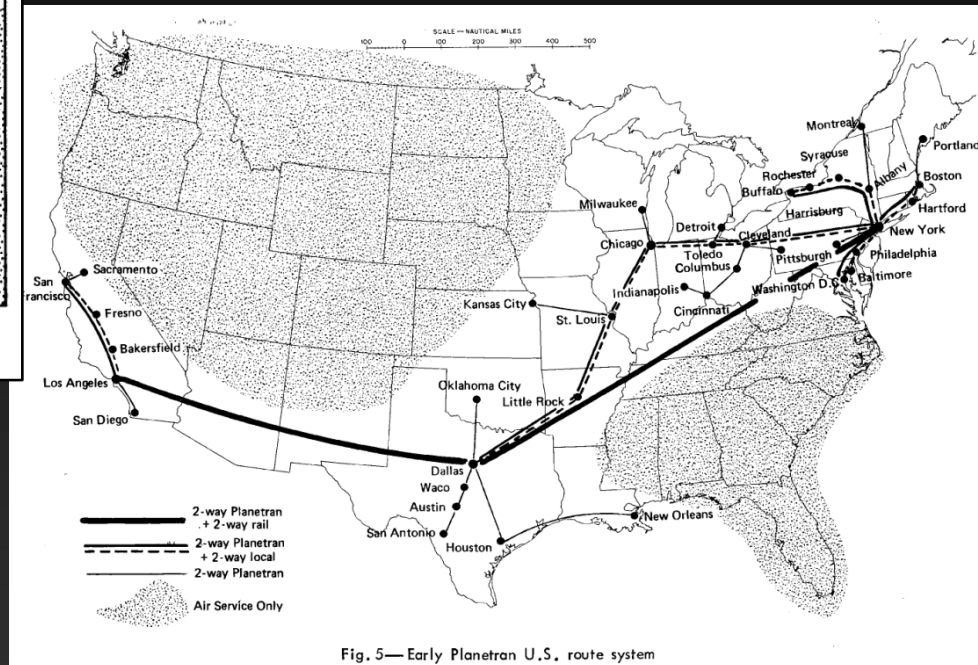
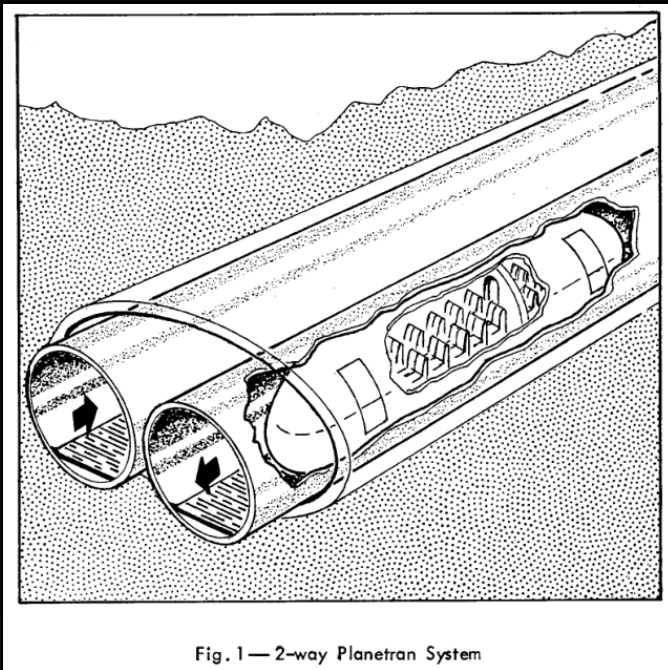
Hyperloop route from Elon Musk / Tesla Motors / SpaceX

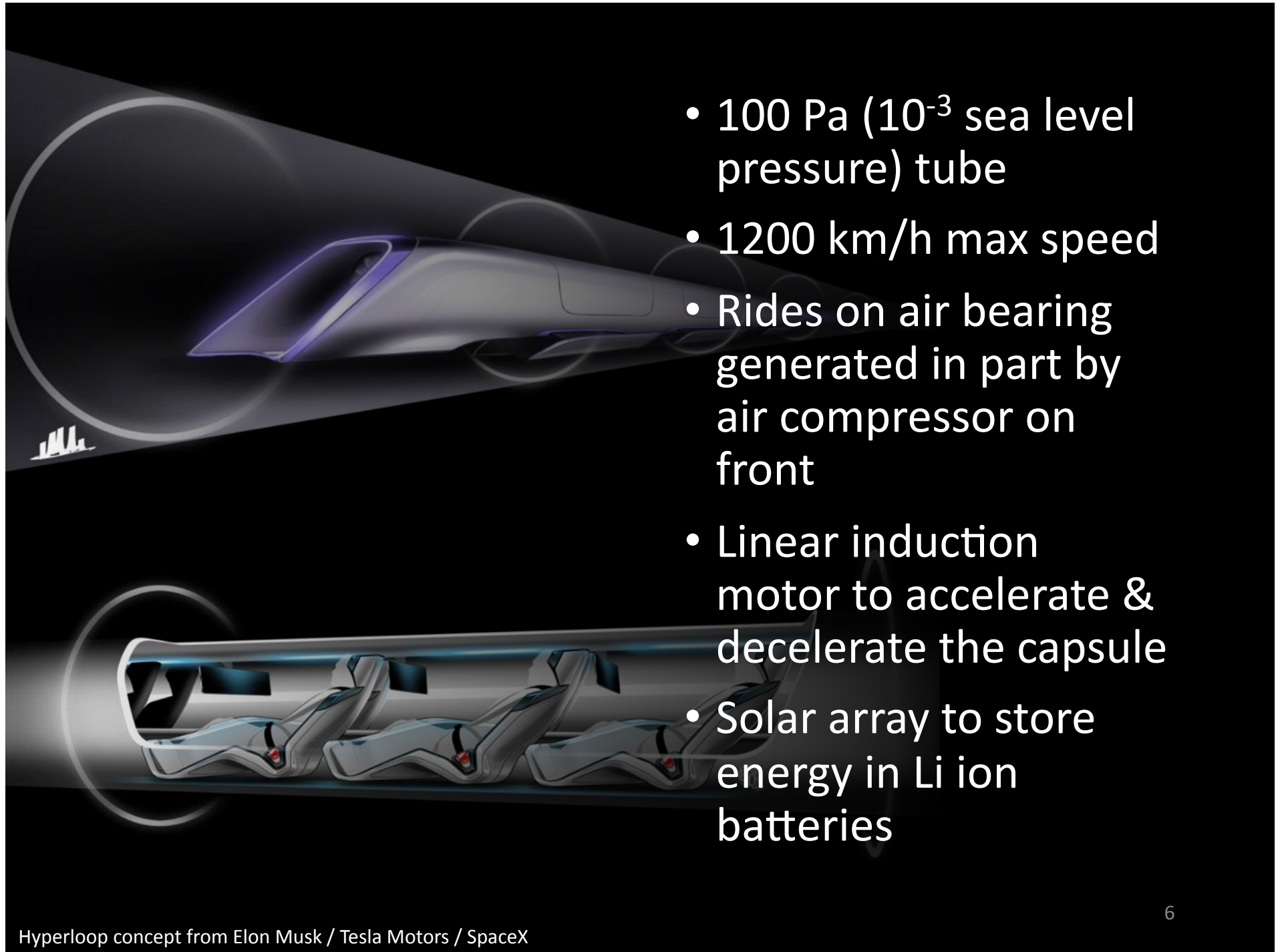




Hyperloop concept from Elon Musk / Tesla Motors / SpaceX

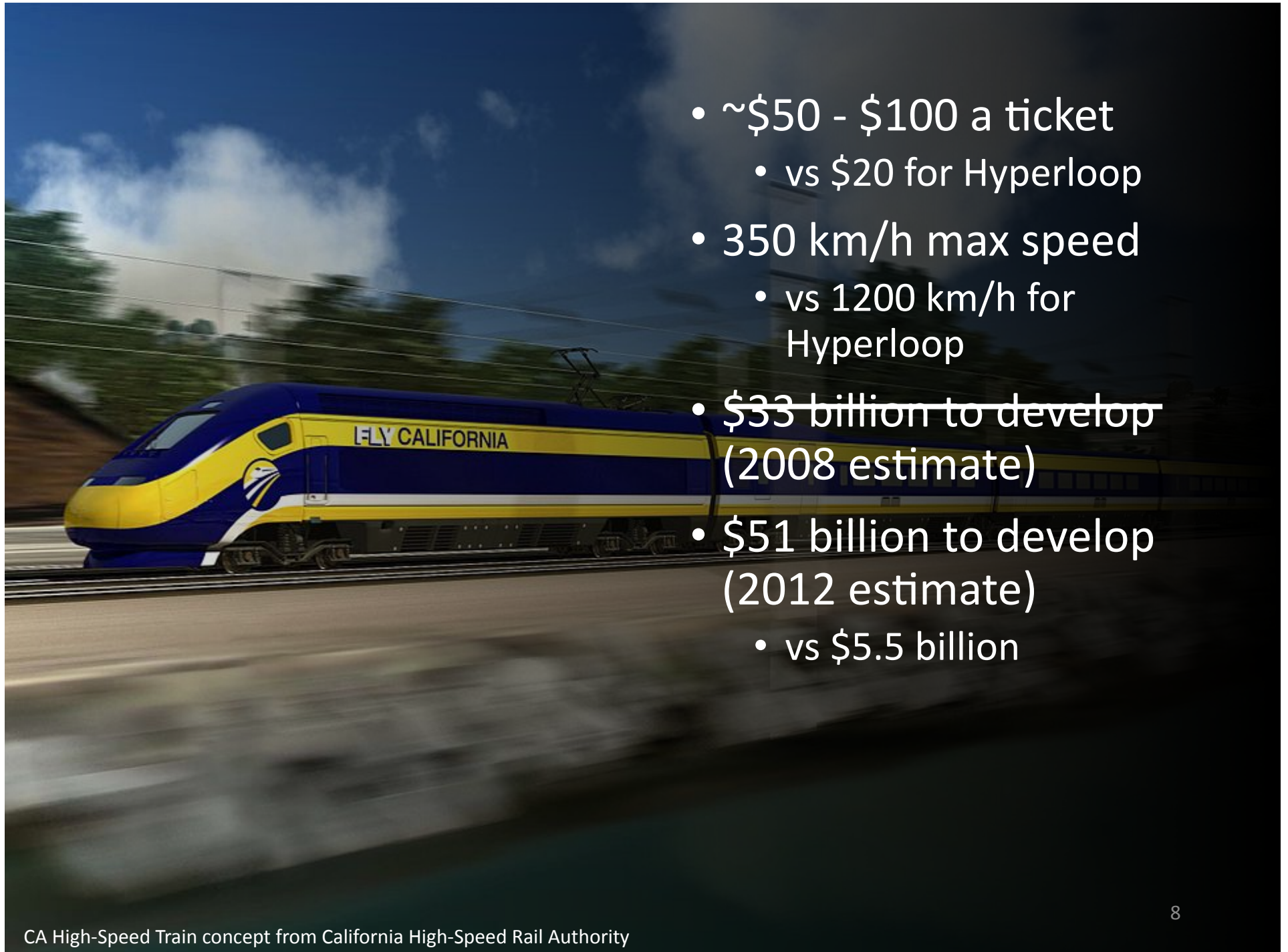
# Similar to RAND Planetran Proposal





# Faster, Cheaper, Better?

- Hyperloop
  - ~\$20 a ticket (plus “operating costs”) (2013 dollars)
  - 35 minute travel time
- Car
  - ~\$50 to drive
  - 335 minute travel time
- Air
  - ~\$160 a ticket
  - 75 minute travel time (not including check-in)



- ~\$50 - \$100 a ticket
  - vs \$20 for Hyperloop
- 350 km/h max speed
  - vs 1200 km/h for Hyperloop
- ~~\$33 billion to develop~~ (2008 estimate)
- \$51 billion to develop (2012 estimate)
  - vs \$5.5 billion



# Megaproject Estimates are Often Bad

- Rail: 45% higher-than-estimated costs
  - Tunnels/Bridges: 34% higher
  - Roads: 20% higher
- 
- Boston's "Big Dig": 196% cost overrun
  - Humber Bridge, UK: 175%
  - Boston-Washington-NY rail: 130%
  - Great Belt rail tunnel, Denmark: 110%

Source: B. Flyvbjerg *et. al.*, "Megaprojects and Risk: An Anatomy of Ambition" (2003).

## Background

When the California “high speed” rail was approved, I was quite disappointed, as I know many others were too. How could it be that the home of Silicon Valley and JPL - doing incredible things like indexing all the world’s knowledge and putting rovers on Mars - would build a bullet train that is both one of the most expensive per mile and **one of the slowest in the world**? Note, I am

Source: “Hyperloop Alpha” white paper (2013).

- ICE 3 (Germany): 320 km/h peak
- TGV POS (France): 320 km/h
- E5/E6 Series Shinkansen (Japan): 320 km/h
- CA High Speed Rail: 350 km/h (planned)

- CHSRA plan says the train will on average be **faster than any train in existence**, and faster than the Transportation Research Board says is safe.

Source: J. Vranich and W. Cox, “California High Speed Rail: An Updated Due Diligence Report” (2013).

Another extreme is the approach, advocated by Rand and ET3, of drawing a hard or near hard vacuum in the tube and then using an electromagnetic suspension. The problem with this approach is that it is incredibly hard to maintain a near vacuum in a room, let alone 700 miles (round trip) of large tube with dozens of station gateways and thousands of pods entering and exiting every day. All it takes is one leaky seal or a small crack somewhere in the hundreds of miles of tube and the whole system stops working.

However, a low pressure (vs. almost no pressure) system set to a level where standard commercial pumps could easily overcome an air leak and the transport pods could handle variable air density would be inherently robust.

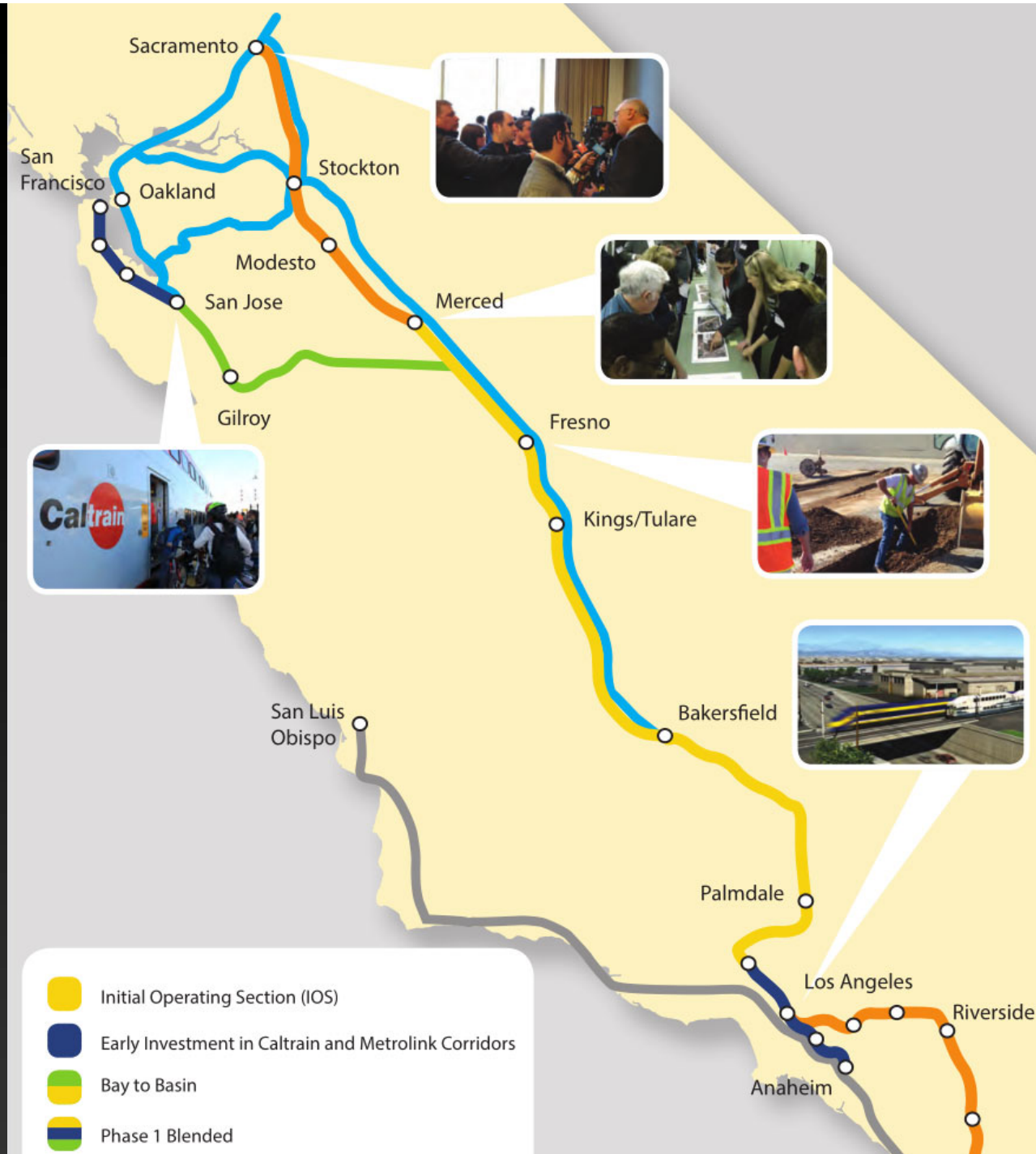
Just as aircraft climb to high altitudes to travel through less dense air, Hyperloop encloses the capsules in a reduced pressure tube. The pressure of air in Hyperloop is about 1/6 the pressure of the atmosphere on Mars. This is an operating pressure of 100 Pascals, which reduces the drag force of the air by 1,000 times relative to sea level conditions and would be equivalent to flying above 150,000 feet altitude. A hard vacuum is avoided as vacuums are expensive and difficult to maintain compared with low pressure solutions.

Source: "Hyperloop Alpha" white paper (2013).

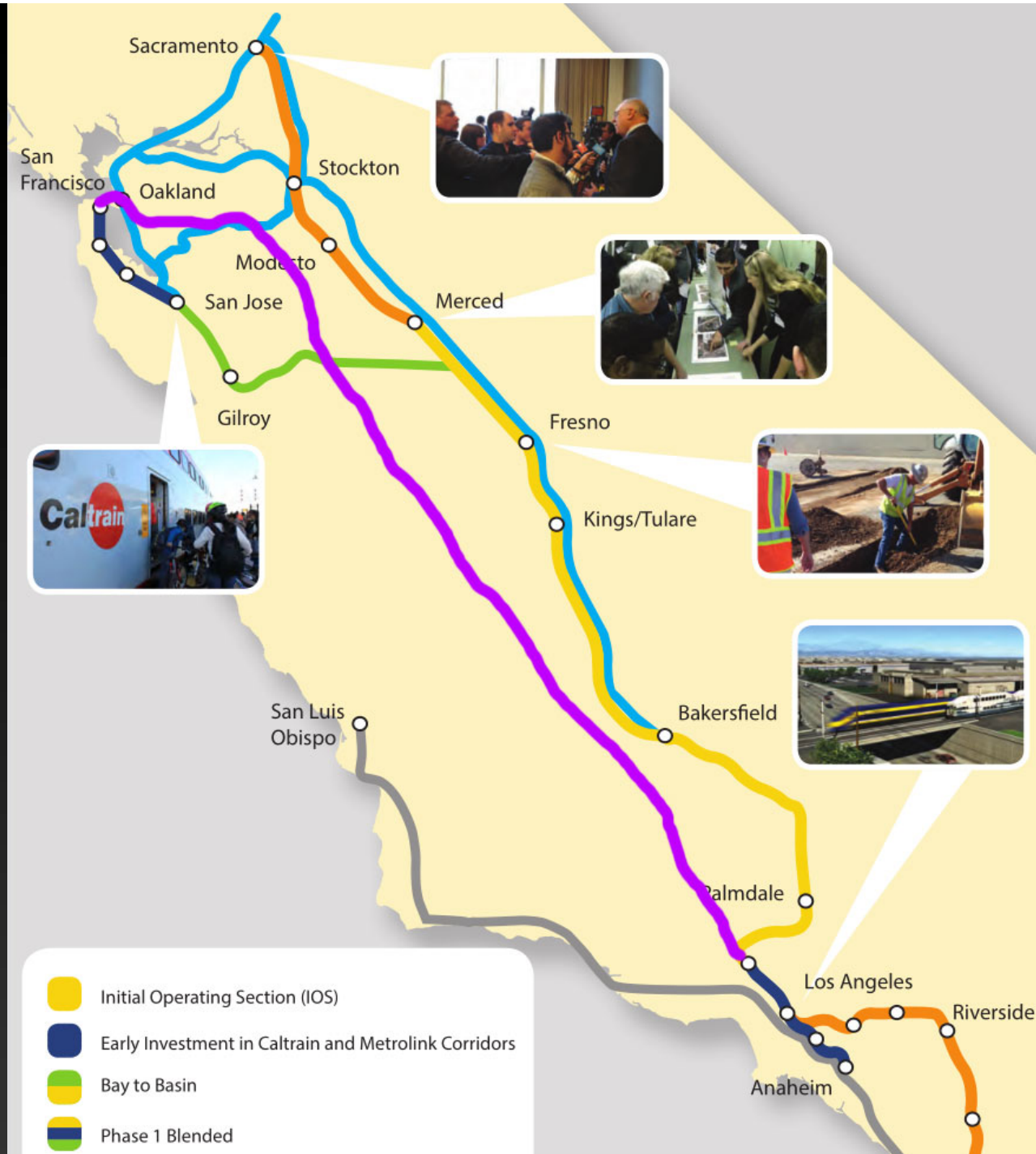
Cars travel in a reduced atmosphere of 0.1% of sea level pressure (equivalent to about 170,000 ft altitude). This level of vacuum is not difficult to achieve requiring only "roughing pumps." Large fusion power

101 Pa

Source: R. Salter, "Trans-Planetary Subway Systems – A Burgeoning Capability" (1978).







# The Questions the Hyperloop White Paper Seeks to Answer

- “Why can’t we have a faster train between San Francisco and Los Angeles?”
- “How do we make a safer train?”
- “How do we reduce train costs?”
- Answer: COMPLETELY NEW TECHNOLOGY



# The Questions the Hyperloop White Paper Seeks to Answer

- “Is the Hyperloop technically feasible?”
- Answer: COMPLETELY NEW TECHNOLOGY



# Focus is on Technology

- From the Hyperloop Alpha paper Table of Contents
  - 4.1 Capsule (construction, power, propulsion)
  - 4.2 Tube (construction, pylons, stations)
  - 4.3 Propulsion (rotor/stator, energy storage)
  - 4.4 Route (optimize to minimize g-forces, easements)
  - 4.5 Safety and Reliability (power outage, earthquakes)
  - 4.6 Cost

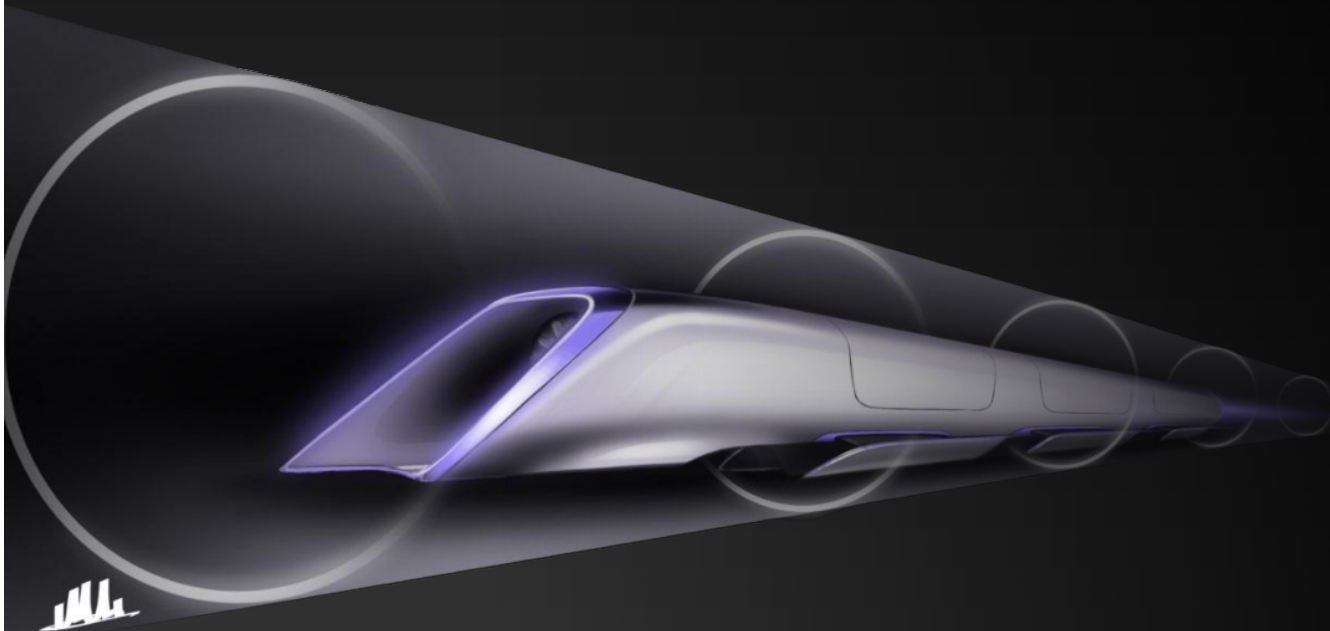




Segway picture from Gawrisch

# The Questions the Hyperloop White Paper Seeks to Answer

- “Is the Hyperloop technically feasible?”
- Not: “Can we really build it?”



# Some Societal Questions About Mass Transit

- How do you pay for it? (Funding)
- Who's going to try to kill it? (Competition)
- Where do you put it? (Location)



# Private or Public Funding?

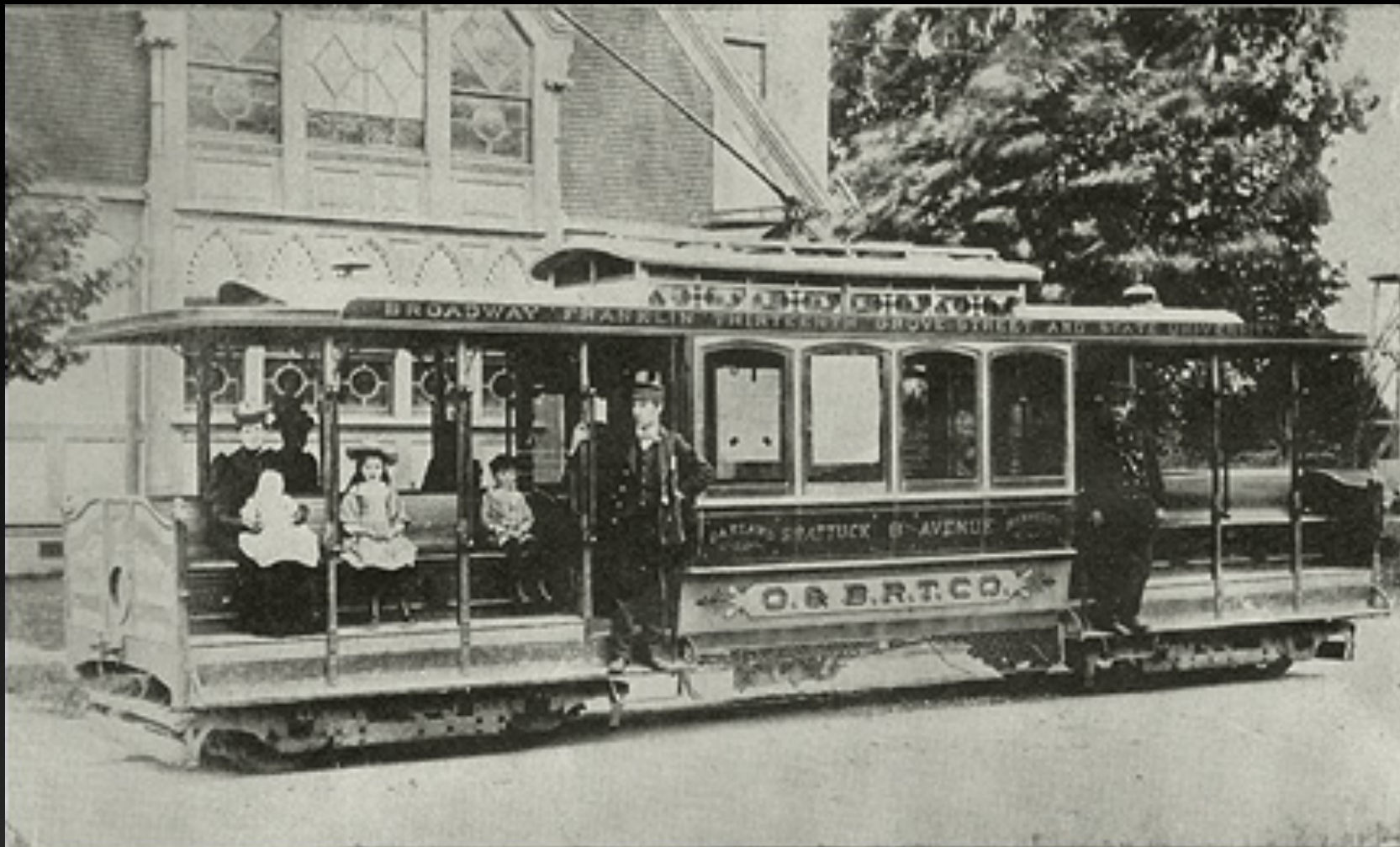




# Will Investors Accept 20 Years to Profitability?

transported each year on Hyperloop. The total cost of Hyperloop in this analysis is under \$6 billion USD. Amortizing this capital cost over 20 years and adding daily operational costs gives a total of about \$20 USD (in current year dollars) plus operating costs per one-way ticket on the passenger Hyperloop.

Source: "Hyperloop Alpha" white paper (2013).

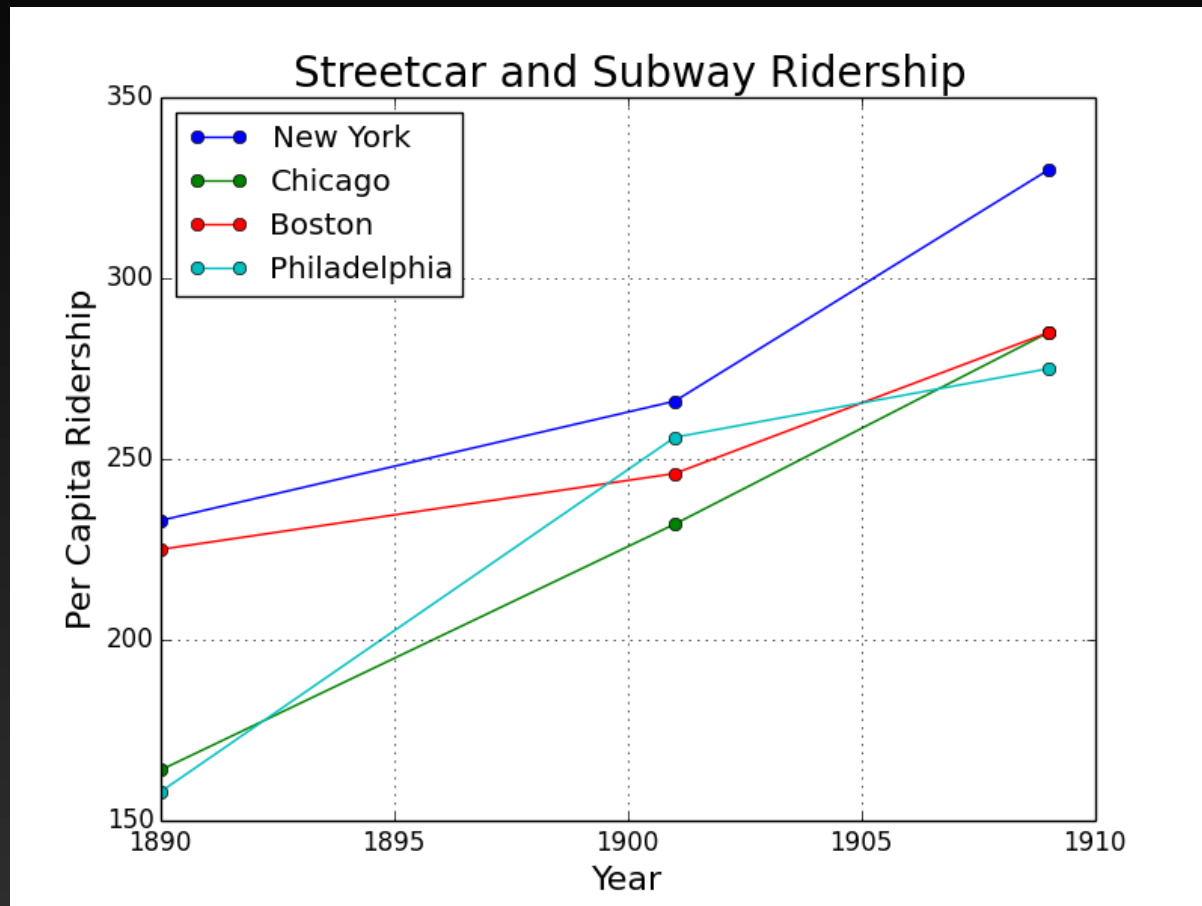


**OAKLAND & BERKELEY RAPID TRANSIT car 8 on Dana Street at Bancroft Way in Berkeley about 1892. Conductor is J. Woods and Motorman Ed Ervy.  
From collection of the late Harry Kelton.**

# Electric Street Railways

- Primary US form of transit at the start of the 20<sup>th</sup> century
- Most were privately owned and investor-financed
- Electric power companies often owned them
- Profitable for several reasons
  - Deflation until 1900; low inflation thereafter
  - Low interest payments on infrastructure debt
  - Low wages and long workdays

# Mass Transit Ridership Exploded

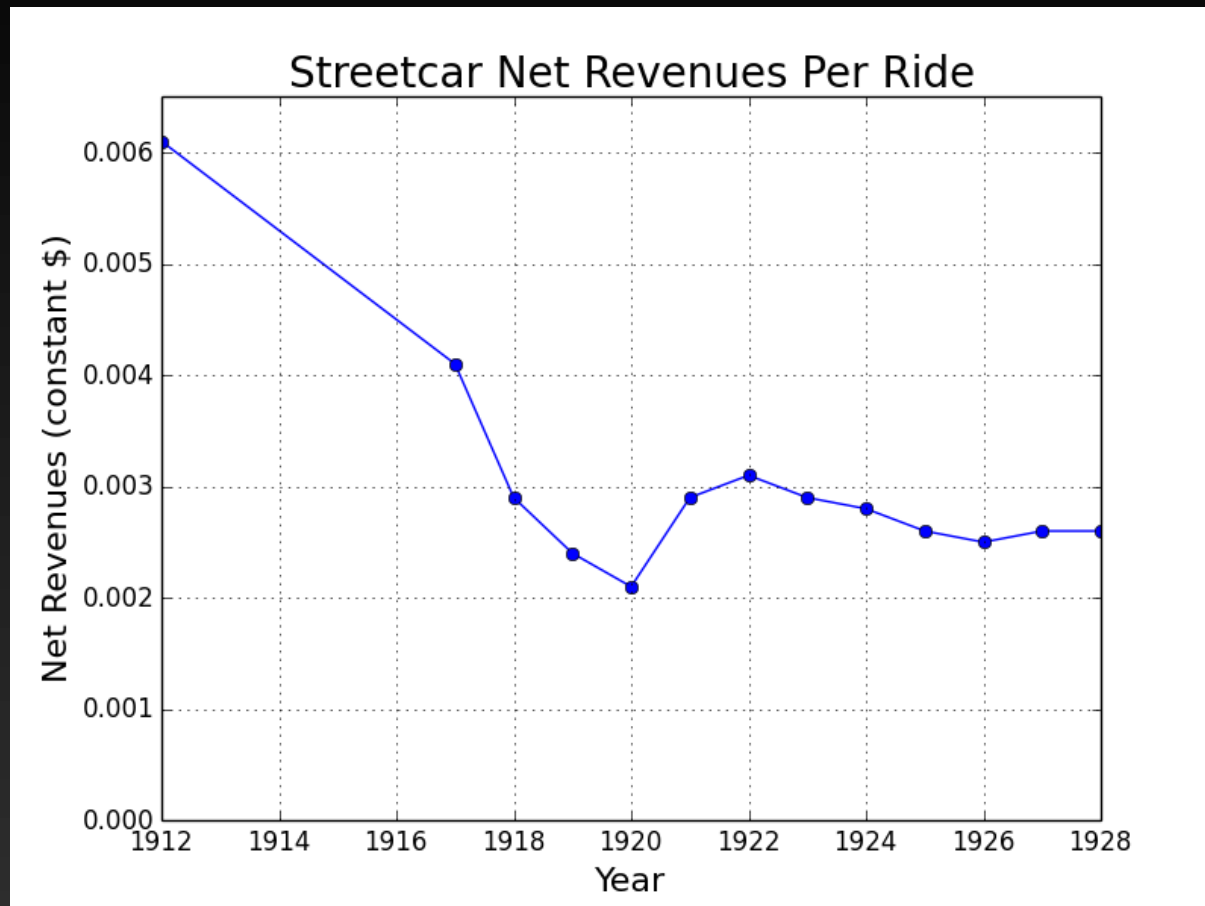




# World War I Wounded Streetcars

- From 1916 to 1920, inflation soared
- 1920 consumer prices were 183% of 1916 prices
- Streetcar wages: 194%
- Operating expenses: 223%
- Streetcar fares: 137%
- Net revenues: 90%

# Net Revenues Plummeted



# World War I Wounded Streetcars

- From 1916 to 1920, inflation soared
  - 1920 consumer prices were 183% of 1916 prices
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  - Net revenues: 90%
- 
- Aging fleets, limited reinvestment, credit standing damaged, and road usage conflicts with cars

# Public Funding Became the Norm

- In 1959, Dilworth (Philadelphia mayor) and Symes (chairman of the Pennsylvania Railroad) pushed for government funding and public ownership in response to the city's "hollowing out"
  - Previously, cities and transportation companies had resisted public funding and especially public ownership
- State legislatures were uninterested, so Dilworth and Symes put together a coalition of mayors and railroads and approached the federal government
- In 1961 Congress authorized loans and grants for urban mass transit

# New York Subway System Shows the Shift

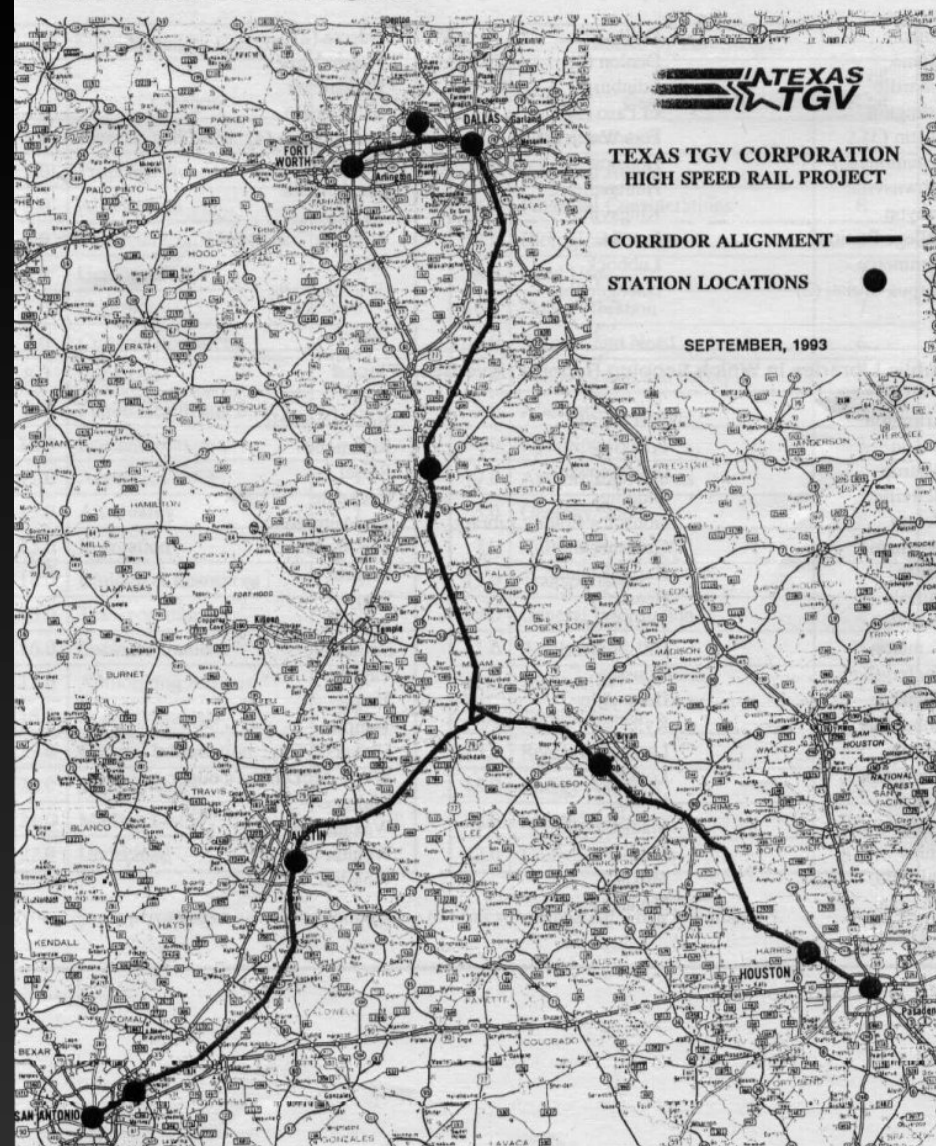




# Texas Tried Private Funding for High Speed Rail in 1989

- Texas High Speed Rail Act (SB 1190, Session 71(R), 1989) created Texas High Speed Rail Authority
  - Privately-financed companies only
- Texas T.G.V.
  - US, Canadian, and French consortium spearheaded by Morrison Knudsen
  - Stockholders: Morrison Knudsen, Mannai Investment Company, Brad Corbett, Ben Barnes (former TX Lieutenant Governor)

Texas TGV Preferred Corridor Alignment

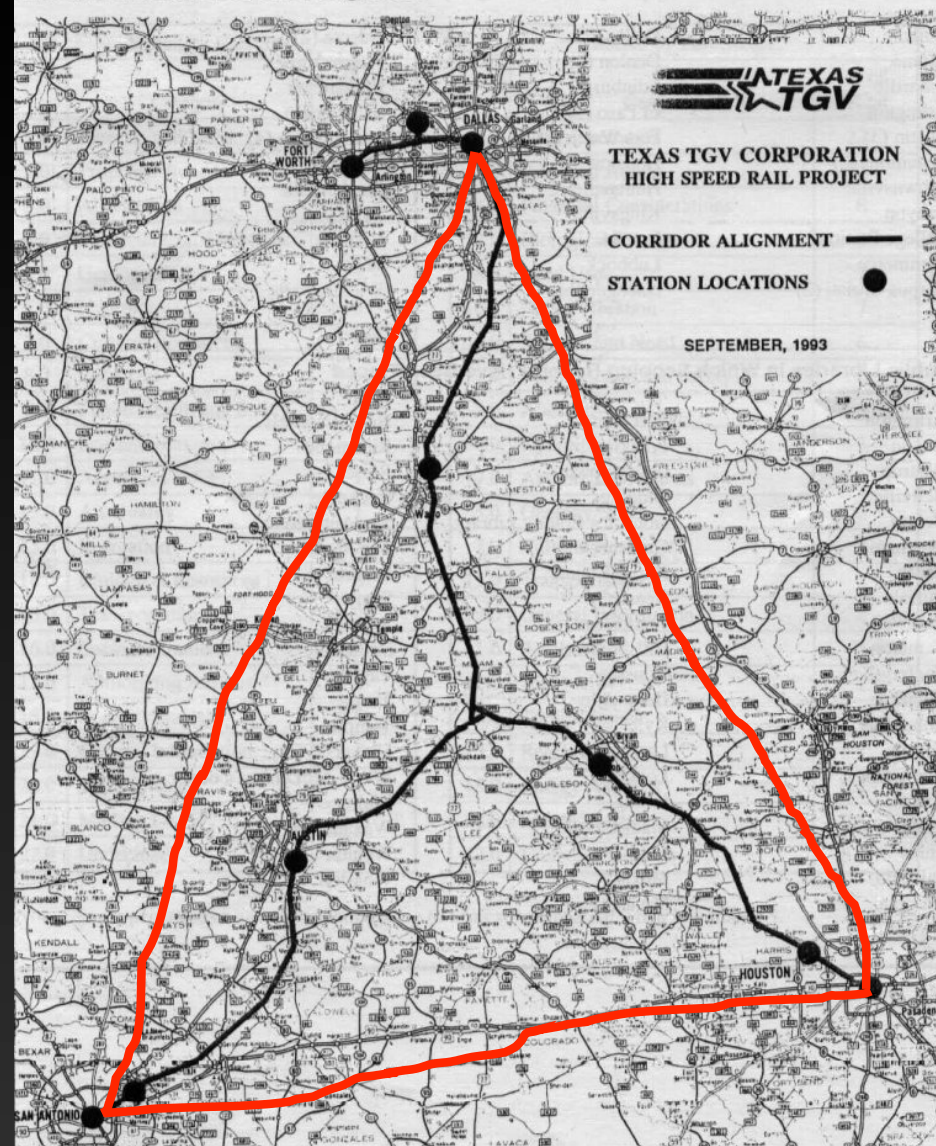


# Texas T.G.V. Couldn't Get Funding

- On May 28, 1991, Texas High-Speed Rail Authority awarded Texas T.G.V. a franchise
  - Required \$170 million equity financing by 31 Dec 1992
- Texas T.G.V. misses the deadline
  - The Authority pushes the deadline to 31 Dec 1993
- November 29, 1993, Texas T.G.V. issued a securities offering
- Less than two weeks later, Morrison Knudsen cancels the offering
- Texas cancels the franchise in 1994

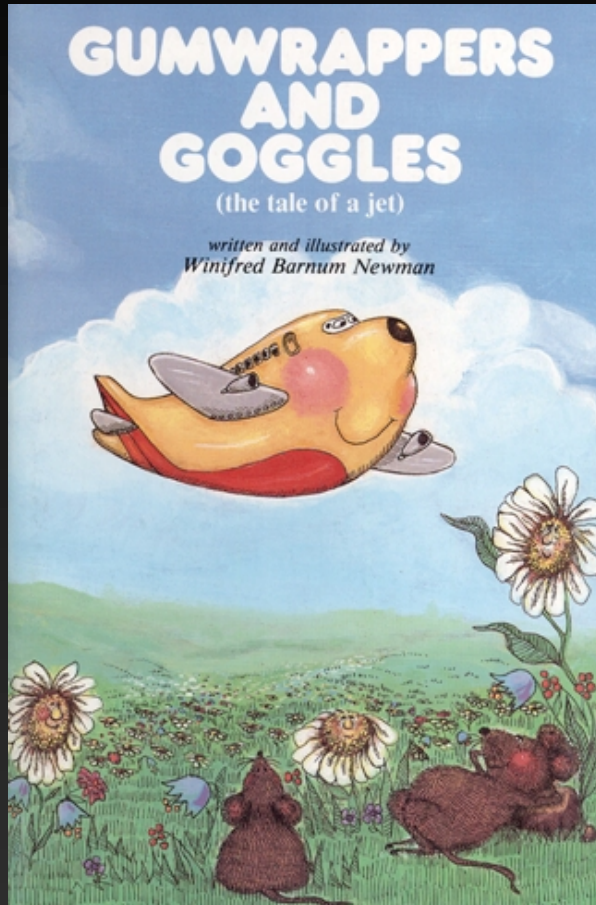


Texas TGV Preferred Corridor Alignment





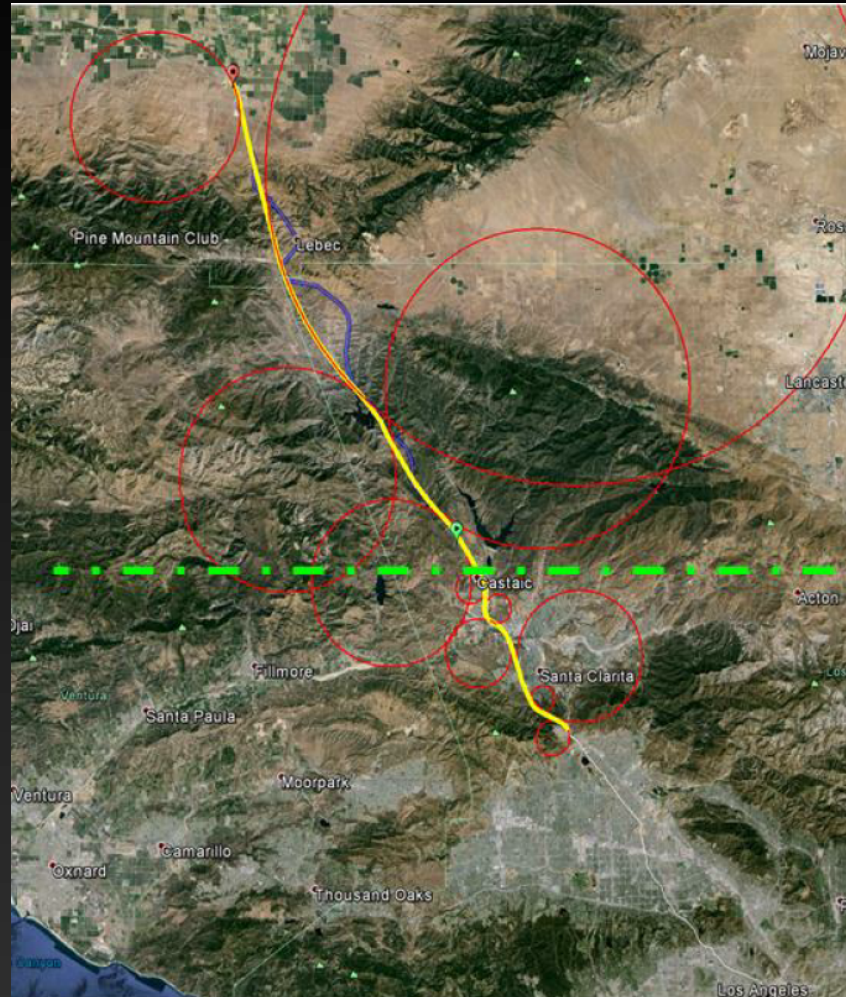
# Southwest as Scrappy Underdog



# Hotels and Fast Food Restaurants Lobbied Against the Texas Train



# Location, Location, Location



Source: "Hyperloop Alpha" white paper (2013).



# Eminent Domain Stirs Up Strong Feelings

## California High-Speed Rail Project



If your property may be affected by the California High-Speed Rail project, it is important that you **contact the Peterson Law Group, P.C.** for a free consultation about your legal rights. AV Rated attorney John S. Peterson has

cases. Our firm will  
for the value of your  
legal concerns, call

One of the parcels to be condemned belongs to Rob Solley of Fresno, who owns the former Horn Photo building on Belmont Avenue east of Weber Avenue. Solley said he and agents for the rail authority disagree on the value of the 4,760-square-foot property and the 1930s-era building.

Solley didn't go into detail on his asking price or the authority's offer on the property, which has an assessed value of \$51,382 according to Fresno County property records. But he said he is concerned about the property sales information that right-of-way appraisers selected to make their opening offer for his parcel.

"We were hoping to avoid eminent domain, but the difference is substantial — there's a large divide there," Solley said. "I've been a real estate investor for years, and I had a problem with some of the comparables they use to come up with the value. ... It looked to me like they cherry-pick

Regardless of how someone answers these questions, the process of land acquisition by the California High-Speed Rail Authority should concern everyone. It has some uncomfortable similarities to how the People's Republic of China relocates people and demolishes homes and small businesses to build massive infrastructure projects under its system of "State Capitalism." Some California leaders think highly of the Chinese plans and initiatives to advance society with ambitious public works projects – see [Governor Jerry Brown Praises Chinese for Bullet Train](#).

Top: Peterson Law Group.

Middle: "State seeks to condemn first Fresno sites for high-speed rail project", Fresno Bee (8 Dec 2013). Bottom: FlashReport blog.

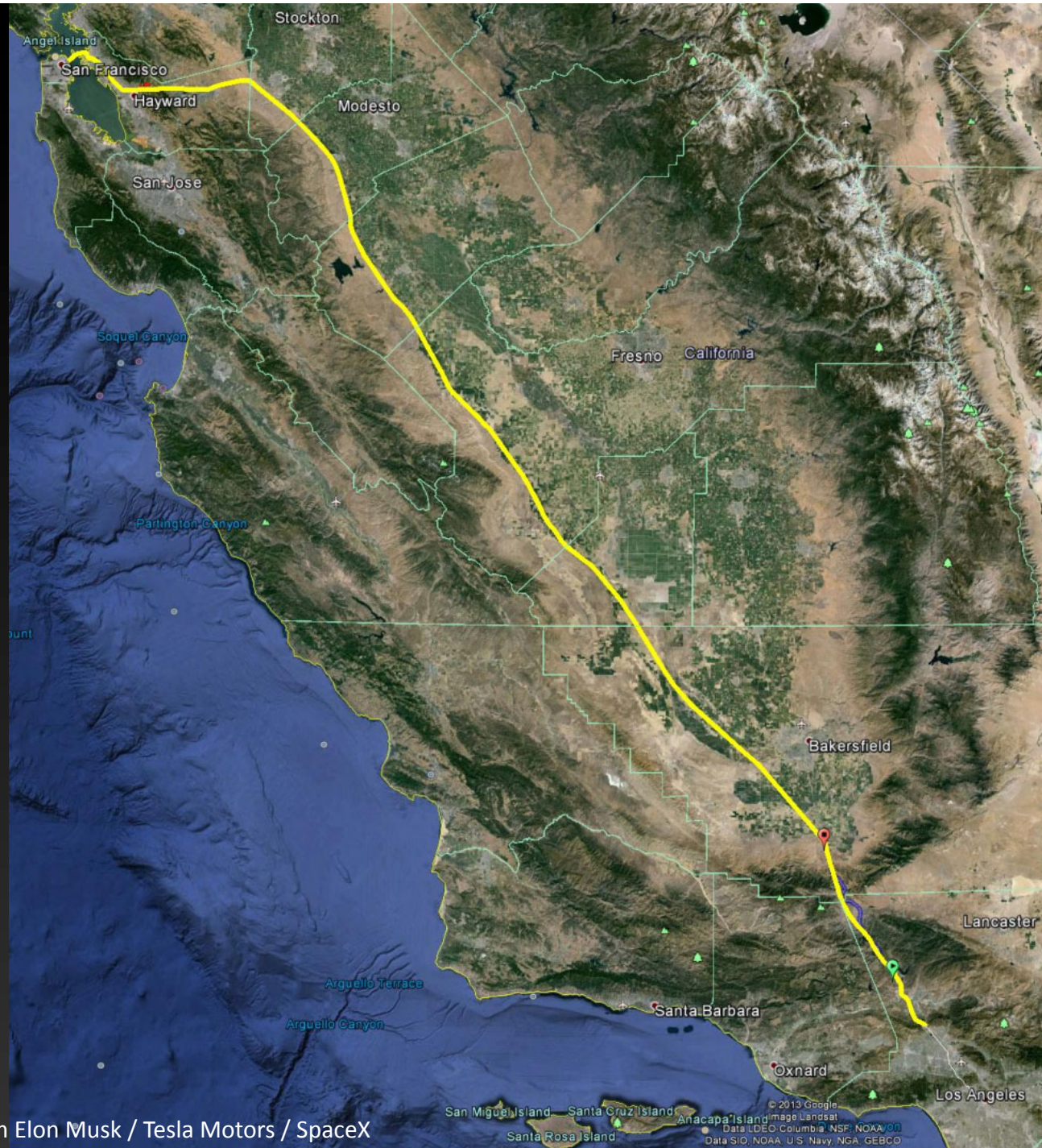


# How Would Pylons Be Viewed?

Even when the Hyperloop path deviates from the highway, it will cause minimal disruption to farmland roughly comparable to a tree or telephone pole, which farmers deal with all the time. A ground based high speed rail system by

- More infrastructure than a free-standing tree or telephone pole
- While wind farms and transmission lines don't appear to depress property values, the perception is that they do. Hyperloop pylons and tubes would likely suffer from the same perception.





Hyperloop route from Elon Musk / Tesla Motors / SpaceX



# Ideal Rocket Equation

$$\Delta v = I_{sp} g_0 \ln \frac{m_{full}}{m_{empty}}$$





# Solution: Nuclear Bombs Push Your Spacecraft



# The Hyperloop is Where Technology Meets Society

- Why can't we have a faster train between San Francisco and Los Angeles?
- How do we make a safer train?
- How do we reduce train costs?
- How do you pay for it? (Funding)
- Who's going to try to kill it? (Competition)
- Where do you put it? (Location)